Problems in Growing Tomatoes in Illinois

By W. A. Huelsen

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CONTENTS

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By W. A. Huelsen, Associate Chief in Olericulture

BECAUSE of wide variations in yield from year to year, sustained profits from tomato growing in Illinois have been difficult to come by, especially on the dark soils of the northern and central parts of the state. During the ten years 1927-1936 tomatoes grown in Illinois for canning averaged 3.2 tons an acre, but in the drouth years of 1934 and 1936 the yields were only 1.1 and 2.3 tons respectively. In 1937, a favorable year, the average reached 4.9 tons, but in 1938 it dropped back to 3.2 tons. The wide variations in yield have been owing mainly to the pronounced differences from year to year in amounts of rainfall and range of temperatures, coupled with the fact that some varieties of tomatoes tend to produce very low yields on dark fertile soils during a hot dry season.

Despite the hazardous nature of the tomato crop, however, the acreage grown in Illinois for canning has increased greatly in the past few years. The average area grown for canning during the five years 1934-1938 was 11,460 acres, compared with an average of 7,300 for the ten-year period 1927-1936. Most of this increase has occurred in northern and central Illinois. In contrast, the acreage of tomatoes planted for the fresh-vegetable market has declined from an estimated average of 4,300 acres in 1928-1932 to an estimated average of 3,270 acres in 1934-1937.

Because of these conditions—the expanding acreage and the hazardous nature of the crop—together with very rapid changes in growing methods, there is a wide-spread demand for information on tomato growing in Illinois; and in this publication an effort is made to bring together the latest available information and to interpret it in terms of Illinois conditions.

Unfortunately the amount of experimental work dealing with tomato growing in this state, especially in the central and northern sections, has been rather limited, and considerable latitude must therefore be granted for errors in attempting to make practical interpretations of experiments conducted in other states. The special difficulties in growing tomatoes as a prairie farm crop may never be entirely eliminated, for it is known that tomatoes frequently behave under

Illinois conditions in ways very different from those encountered elsewhere, but it is very encouraging to note that some of the newer experimental work shows great promise in eliminating a few of the worst crop hazards.

GROWING TOMATOES ON PRAIRIE SOILS

Comparatively few tomatoes were grown in the prairie sections of the Middle West prior to 1934. The largest acreage in the country is in Indiana, most of it south of the Wabash river, but this section is not, strictly speaking, a prairie province, nor does it have the same climate as the open prairies of Illinois. To the west of Illinois the Ozark hill region of Missouri and Arkansas is the most prominent tomato-growing area, but there the region is timbered and the yields are usually lower than in Illinois and Indiana.

When tomatoes are grown on the Illinois prairie, the plants are compelled to adapt themselves to several conditions which are not met in the tomato-growing regions east of Illinois, where most of the experimental work has been done. These conditions are:

1. Great fluctuations in temperature, with recurrent hot winds, accompanied by low humidity.

2. Scanty rainfall or at best uneven rainfall during the growing season.

3. Soils high in organic matter and frequently with comparatively high levels of available nitrogen.

4. Comparatively slow drainage, often due to more or less plastic subsoils.

Before discussing methods of growing, the relation of these factors to yields should be made clear.

Blossom Drop Correlated With High Temperature and Hot Winds

Hot winds and low relative humidity frequently accompany periods of high temperature in all parts of Illinois.[a] Altho tomatoes are of tropical origin and the plants are extremely resistant to drouth, they do

[a]In northern Illinois the highest recorded temperature is 112° F. at Ottawa; in central Illinois 112° F. at Hillsboro and Mt. Pulaski; and in southern Illinois 115° F. at Centralia. These temperatures are the extremes, of course, but periods of 95° to 100° F. are encountered almost every year in all parts of Illinois. (U. S. Dept. Agr. Weather Bur., Climatic summary of the United States. Secs. 56-58)

not bear fruits under drouth conditions. Oklahoma experiments[13, 16*] show that immature tomato blossoms drop most rapidly during periods of extreme heat and drouth owing to the increase in transpiration (loss of water from the plants); that blossom drop increases as humidity decreases; and that because of slow pollen-tube growth the blossoms may be destroyed if weather conditions are unfavorable after pollination has occurred.

As blossom drop was general thruout Illinois in 1934 and 1936, accompanying a sudden expansion of acreage, the attention of many growers was forcibly directed to it. It was also severe at the Illinois Station in 1930, 1931, and 1933. Blossom drop results in a serious reduction in crop yields because of the scanty set of fruits and the continued growth of vines, frequently to enormous size.

The grower can have no direct control over hot winds, drouth, and high temperatures. He may, however, secure some protection from hot winds by means of windbreaks, from drouth by means of irrigation and selection of variety, and he may lower temperatures in his fields by combining windbreak protection with irrigation.

Stands of timber make the best windbreaks; but if timber is not available, strips of field corn 10 rows or more wide may be grown at intervals across the tomato field, the strips running east and west with a solid block of corn west of the tomatoes. Smith[16*] considered windbreaks of much importance in preventing blossom drop, according to tests in Oklahoma, tho his view is in disagreement with the experimental results of Herron,[16*] who assumed that hot winds had little to do with blossom drop.

Topography is also of importance as a means of protection from hot winds, with the northern and eastern slopes offering much greater protection from the prevailing southwesterly winds than those having a southern or western exposure.

Irrigation has been advocated as an aid in controlling blossom drop, tho the results of experiments at the Oklahoma Station comparing irrigated with nonirrigated tomatoes are contradictory.[13*] It seems probable, however, that given the proper protection from direct exposure to high winds, blossom drop can be reduced by means of irrigation, especially the overhead type, because irrigation reduces soil temperatures, increases local humidity and, of course, increases the available moisture. *Combining windbreak protection with irrigation seems to be a logical method of preventing blossom drop.*

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*These numbers refer to literature citations on page 48.

Protecting Tomatoes by Interplanting With Corn

During the severe drouths of 1934 and 1936, a few tomato growers attempted to prevent blossom drop by means of the protection afforded by strips of corn planted across their fields. Unfortunately, no reliable estimates of the yields obtained where this practice was used are available. During 1934 it was observed that weeds gave tomato plants considerable protection from the heat. A number of growers set their plants in rows 6 feet apart, and having difficulty in "breaking out the middles" with the tools at hand simply let narrow strips of weeds grow in each "middle." The protection thus afforded apparently favored a better set of fruits and increased the yields.

Since, however, a protective crop may compete directly with the tomatoes for nutrients in the soil, the results of systematic research need to be examined before definite statements can be made as to the value of interplanting for protection. Two-year results of tests begun by the Illinois Station in 1937 to determine the effect of protecting tomatoes by interplanting with field corn give considerable commercial promise for interplanting, tho no definite conclusions may be drawn until the experiment encounters more adverse conditions of drouth and heat than the 1937 and 1938 seasons afforded.

Plan of Illinois Experiments.—The Illinois experiment on interplanting tomatoes with corn consists of 30 plots divided into sets of ten as follows:

- 10 plots straight field corn
- 10 plots corn and tomatoes interplanted (5 plots Early Baltimore, 5 plots Illinois Baltimore)
- 10 plots straight tomatoes (5 plots Early Baltimore, 5 plots Illinois Baltimore)

The plan of the three types of plantings is shown in Fig. 1. The 30 plots are laid out in the field in such a manner as to prevent one set of treatments from affecting any of the others.

The field is prepared by cross-marking 42 x 42 inches. Part *A* of Fig. 1 shows how the tomatoes and corn are interplanted. Part *B* shows the arrangement where tomatoes are planted alone. It should be noted that *A* and *B* contain the same number of tomato plants per unit of area, the only difference being the interplanted corn. The distance between tomato plants in both *A* and *B* is 4.95 feet, a standard planting distance; but the actual rows run diagonally across the plots. Part *C* shows the arrangement where corn is planted alone, checked 42 x 42 inches. There are twice as many corn hills per unit of area in *C* as in *A*.

The tomatoes in these experiments are set by hand after the corn appears above ground. The corn is planted by hand, 2 stalks per hill. A hybrid corn was used in 1937, and Reid's Yellow Dent in 1938.

Results of Illinois Experiments.—The yields and the calculated gross returns for one of the two varieties, Early Baltimore, are given in Table 1. The 1937 experiment was laid out on a heavy black clay loam which accounts for the high yields of corn and the relatively poor tomato yields. In 1938 a sloping dark silt loam was used. Both 1937

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T C T C T     T   T   T     C C C C C
C T C T C       T   T       C C C C C
T C T C T     T   T   T     C C C C C
C T C T C       T   T       C C C C C
T C T C T     T   T   T     C C C C C
C T C T C       T   T       C C C C C
T C T C T     T   T   T     C C C C C
C T C T C       T   T       C C C C C
T C T C T     T   T   T     C C C C C
---------     ---------     ---------
    A             B             C
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Fig. 1.—Planting Plan for Testing Interplanting of Tomatoes With Corn

and 1938 were favorable years for tomatoes. Rainfall was sufficient and temperatures were moderate. During the two years of the experiment so far, the interplanted tomatoes matured earlier and produced higher percentages of No. 1 fruits than the tomatoes alone.

An interesting feature of the test is that at representative prices for tomatoes and corn the monetary returns per acre are practically the same for interplanted tomatoes and corn and for tomatoes alone. Altho the yields of U.S. No. 1 tomatoes were low due to delays when the plots should have been picked, the percentages from the interplanted plots were considerably higher, as follows:

	Percentages of U.S. No. 1 tomatoes	
	1937	*1938*
Tomatoes interplanted with corn	37.5	27.0
Tomatoes alone	22.5	11.8

The yields of corn were surprisingly high on the interplanted plots. Compared with yields on the plots of corn alone, they were not reduced by half in spite of the fact that only half as many hills were planted.

TABLE 1.—ACRE-YIELDS AND ACRE-RETURNS FROM TOMATOES AND FIELD CORN INTERPLANTED, AND FROM TOMATOES ALONE AND FIELD CORN ALONE, 1937 AND 1938
(Tomatoes were Early Baltimore variety)

	1937		1938	
	Yield	Returns	Yield	Returns
Interplanted	*bu.*		*bu.*	
Field corn	64.2	$28.89	55.1	$24.80
	tons		*tons*	
Tomatoes—U. S. No. 1	.6	9.60	1.0	16.00
U. S. No. 2	1.6	17.60	3.7	40.70
Total return, corn and tomatoes	....	$56.09	....	$81.50
Tomatoes alone	*tons*		*tons*	
U. S. No. 1	.9	$14.40	.8	$12.80
U. S. No. 2	4.0	44.00	6.8	74.80
Total return, tomatoes alone	....	$58.40	....	$87.60
	bu.		*bu.*	
Corn alone	106.7	$48.02	104.7	$47.12

Note.—Returns from field corn were calculated on the shelled basis, 15 percent moisture, 45 cents a bushel. Tomato returns were calculated on the basis of $16 per ton for U. S. No. 1 and $11 for U. S. No. 2 grades. Any rise in the price of tomatoes without a corresponding increase in corn prices would cause even greater differences in returns.

Effect of Drouth on Maturity and Yields

The amount of rainfall in Illinois[a] annually is usually sufficient to grow tomatoes if it were well distributed, especially during the growing season. Frequently, however, there is a serious shortage of rain during June and July. Soil conditions, when this happens, resemble those of a semiarid climate, and of course affect both the maturity and yields of tomatoes. The early and the late varieties react differently, however, to these conditions, and by making a careful choice of variety a tomato grower can avoid to an appreciable extent the unfavorable effects of drouth and heat. Early-blooming varieties, which set a considerable number of fruits before the weather becomes extremely hot, have become increasingly popular in Illinois during the past few years. These varieties are not subject to excessive vine growth on the more fertile soils and they mature a reasonably good crop before the cool and more humid weather of late summer and fall favors the spread of leaf diseases causing defoliation. During hot weather the fruits of such varieties mature slowly, and few additional blossoms set.

[a]In northern Illinois, 33.36 inches; in central Illinois, 36.65 inches; and in southern Illinois, 41.60 inches. (U. S. Dept. Agr. Weather Bur., Climatic summary of the United States. Secs. 56-58)

TABLE 2.—PROPORTION OF TOTAL TOMATO CROP MATURING DURING DIFFERENT PERIODS IN HARVEST SEASON, AND TOTAL ACRE-YIELDS OF U. S. NO. 1 AND NO. 2 TOMATOES, ON LIGHT- AND ON DARK-COLORED SOIL, IN A YEAR WHEN RAINFALL WAS DEFICIENT AND IN A YEAR WHEN RAINFALL WAS NORMAL

Variety	Soil	Number of trials averaged	Proportion of crop consisting of U. S. No. 1 and No. 2				Total yield of U. S. No. 1 and No. 2 per acre
			Aug. 1-15	Aug. 16-31	Sept. 1-15	Sept. 16-Oct. 10	
1936—Deficient rainfall							
			perct.	*perct.*	*perct.*	*perct.*	*tons*
Early Baltimore	Light-colored silt loam	18	14.7	19.5	9.6	56.2	1.96
Pritchard	Light-colored silt loam	18	17.5	17.1	6.3	59.1	1.66
Early Baltimore	Dark-colored silt loam	15	3.3	11.0	8.4	77.3	4.81
Pritchard	Dark-colored silt loam	15	7.0	13.6	4.3	75.1	4.42
Prairiana	Light-colored silt loam	24	9.7	18.5	6.1	65.7	1.68
Pritchard	Light-colored silt loam	24	17.2	17.9	4.6	60.3	1.85
Prairiana	Dark-colored silt loam	27	1.5	9.3	3.6	85.6	4.34
Pritchard	Dark-colored silt loam	27	6.3	12.4	3.2	78.1	4.12
Illinois Baltimore	Light-colored silt loam	9	4.3	11.0	5.5	79.2	1.49
Marglobe	Light-colored silt loam	9	12.6	15.9	6.1	65.4	.70
Illinois Pride	Light-colored silt loam	18	4.5	10.2	2.6	82.7	1.26
Marglobe	Light-colored silt loam	18	9.9	9.0	3.1	78.0	.84
1937—Normal rainfall							
			Aug. 11-19	Aug. 20-28	Aug. 29-Sept. 6	Sept. 7-16	
Early Baltimore	Light-colored silt loam	33	8.8	14.8	21.6	54.8	9.84
Pritchard	Light-colored silt loam	33	3.6	8.8	24.0	63.6	9.45
Early Baltimore	Black clay loam	45	4.2	8.2	22.1	65.5	6.78
Pritchard	Black clay loam	45	2.1	7.4	22.2	68.3	6.53
Prairiana	Black clay loam	30	1.8	4.2	19.2	74.8	6.24
Pritchard	Black clay loam	30	1.8	6.8	21.9	69.5	6.69
Illinois Baltimore	Light-colored silt loam	45	3.3	8.0	9.9	78.8	5.72
Illinois Pride	Light-colored silt loam	45	1.2	3.6	15.0	80.2	5.85

Note.—Light-colored silt loam was an eroded prairie soil located on a slope, light brown to yellow in color, low in organic matter, nitrogen, and phosphorus. In these tests such soils were manured, and 400 pounds of superphosphate per acre were broadcast. The 1937 series were planted on an old alfalfa sod.

Dark-colored silt loam and black clay loam were high in organic matter, nitrogen, and phosphorus. The relatively low yields on black clay loam in 1937 were due to poor drainage.

Yield characteristics of tomato varieties in an abnormally hot and dry season such as 1936 are quite different from those of the same varieties in seasons, such as 1937 and 1938, when soil moisture is not a limiting factor. In 1936, Early Baltimore, Pritchard and Prairiana, all of which are early-blooming types, yielded more than the later-blooming Illinois Baltimore and Illinois Pride (Table 2). Marglobe, a late, straggly-blooming type, yielded less than 1 ton an acre. But in 1937 and also in 1938, when rainfall was normally distributed, all of the varieties yielded comparatively well. As a matter of fact, in seasons when weather is normal, practically any standard variety will produce a favorable yield in Illinois, but only well-adapted varieties will produce satisfactorily in seasons of heat and drouth.

The effect of blossom drop caused by extremely hot weather on subsequent yields of tomatoes is brought out in Table 2 by the percentages of the total crop picked during consecutive periods of the harvest season. In 1936 all varieties showed a sharp drop in yield during the September 1-15 period. This drop was due to the fact that 6 to 8 weeks earlier (July 15-August 1) extremely hot weather prevailed and the blossoms failed to pollinate. In 1937, however, the temperatures were lower and rainfall higher; and consequently the blossoms could set. None of the varieties showed a drop in yield in 1937 comparable to that in 1936.

The effect of heat and drouth in delaying maturity is also shown by the comparative duration of the 1936 and the 1937 tomato harvest periods. The picking period in 1936 lasted 71 days, but in 1937 it lasted 37 days, only about half as long. The preference for earlier varieties in Illinois has gained momentum because numerous tests have shown that the size of the crop is determined to a considerable extent by the yields obtained *before* the break due to blossom drop occurs. This is not well illustrated by the results in Table 2, for 1936, because of the extremely low yields. The following data from the drouth year of 1934 and the more normal season of 1935 show the close relationship between earliness of maturity and total yields:

	Percentage of total crop picked before Sept. 1	*Total yields (Tons U. S. No. 1 and No. 2)*
1934		
Early Baltimore	17.0	7.57
Illinois Baltimore	13.8	5.70
Marglobe	4.9	3.83
Illinois Pride	2.2	3.86
1935		
Prairiana	46.0	6.52
Early Baltimore	37.7	6.52

Pritchard	36.4	6.45
Illinois Baltimore	29.8	5.70
Illinois Pride	29.6	5.43
Marglobe	29.2	5.31

This tendency for the second-early varieties to produce higher yields than later-maturing types has been observed by both growers and canners in most parts of Illinois. The earlier varieties not only mature fruit earlier than the later types but they bear fruit just as long in the fall as the late types. Defoliation due to disease or possibly to lack of nutrients is the principal cause for the premature ending of the picking season. When the foliage is retained, as it usually is on the more fertile Illinois soils, especially in dry seasons, early varieties have a long harvest season and the yields are higher than the yields of the late varieties.

Choosing Variety to Fit the Soil

Until a few years ago the dark prairie soils of Illinois were believed to be entirely unsuited to tomato growing because of crop failures in adverse seasons. In favorable seasons these soils produced large crops of tomatoes, but in hot, dry seasons the yields were very low and maturity extremely late. The varieties grown were almost exclusively the late-maturing varieties, such as Marglobe, Greater Baltimore, Indiana Baltimore, Matchless, Stone, and Mississippi Girl. The factors limiting the yields of these varieties on the dark prairie soils were failure of blossoms to set and excessive growth of vine.

Because of crop failures with the late varieties in the drouth years of 1934 and 1936, many of the growers in northern and central Illinois planted earlier-maturing varieties in 1937 and 1938, such as Pritchard, Early Baltimore, John Baer, and J.T.D. The earlier-maturing varieties, as was pointed out on pages 8 to 10, blossom earlier and are smaller vined than the late types, and thus offer definite advantages in drouth years. Some of the canning companies, especially in northern Illinois, are now making a practice of correlating tomato varieties with the types of soil on which they are grown.

Why Dark Soils Require Earlier Varieties.—Altho a great deal of attention[7*] has been given to the carbohydrate-nitrogen relations of tomato plants grown under carefully controlled conditions, no detailed studies have been made on the dark prairie soils of the Middle West under field conditions. It is known, however, that these soils accumulate large quantities of nitrogen salts during protracted periods of light rainfall and high temperatures. Under such conditions the blossom fails to develop normally and abscission occurs. The accumulated nitrogen salts become available to the plant as soon as a few showers fall, an occurrence to be looked for in any season after August 15. Since the plant is still in the vegetative stage, owing to blossom drop, a rapid growth follows and further blooming and setting depends upon the weather, the amount of nitrogen available, and the varietal habit.

The late-blooming, late-maturing, large-vined varieties are subject to blossom drop. In dry seasons on dark soil this tendency is particularly aggravated, with the result that sometimes no tomatoes are harvested from such varieties at all. The earlier varieties, on the other hand, usually set fruits before the weather becomes extremely hot (page 8), and tho they do not continue to set fruits during the hot dry weather, they are prevented from running away in vine growth when the drouth is broken by the fact that they are bearing fruits, on the one hand, and that they are naturally smaller-vined types, on the other.

Thus it should be clear that the dark soils are adapted only to early varieties. Light-colored soils, however, may also be adapted to early varieties, the factor involved being the degree of fertility (nutrients and organic matter). When the fertility is low the large-vined late-maturing types are recommended because nitrogen does not reach the same high levels as on dark-colored soils, and consequently vine growth is never excessive.

Tests Showing Effect of Soil on Varietal Yields.—The early varieties, such as Pritchard, Early Baltimore, John Baer, and Prairiana, may have strikingly different characters on dark- and light-colored soils, the divergence depending upon the weather and the accumulation of nitrogen in the soil. In seasons of relatively moderate temperatures and fair rainfall distribution such as 1935, 1937 and 1938, the early varieties were practically the same in appearance, maturity, and yield on the two soil types, but in years of deficient rainfall and abnormally high temperatures, 1934 and 1936 for example, the appearance was radically different. The yields varied greatly and on dark soils maturity was much later. The yields in Table 2 show the effects of these tendencies, but the facts are much more evident from the following averages of five trials:

Picking period	*Tons per acre, U.S. No. 1 and U.S. No. 2*			
	Early Baltimore		*Pritchard*	
1935	*Light soil*	*Dark soil*	*Light soil*	*Dark soil*
July 15-30	.03	.01	.07	.08
Aug. 1-15	.66	.28	.78	.43
Aug. 16-31	1.77	3.33	1.50	3.11

Sept. 1-15	2.20	2.06	2.96	1.94
Sept. 16-30	1.86	1.50	1.14	1.07
Total	6.52	7.18	6.45	6.63
1936				
July 28-Aug. 15	.30	.18	.34	.33
Aug. 16-31	.40	.57	.26	.64
Sept. 1-15	.22	.53	.13	.23
Sept. 16-Oct. 10	1.20	4.21	1.02	3.32
Total	2.12	5.49	1.75	4.52

In the relatively normal year of 1935 the yields on the dark- and on the light-colored soils were about equal, but maturity was earlier on the dark soils. Both soils were in a good state of fertility. In contrast, on the same two soils, the yields during the drouth year of 1936 were much better on the dark soil. Maturities were later, but yields were more than double. The vines on the dark soils in 1936 were approximately four times as large, and the marketable fruits were also heavier, as shown by the following average weights per fruit.

	Early Baltimore		*Pritchard*	
	Light soil	*Dark soil*	*Light soil*	*Dark soil*
1935	*oz.*	*oz.*	*oz.*	*oz.*
Average weight	5.38	5.82	5.28	5.23
1936				
Average weight	3.82	4.56	3.98	4.30

Late-maturing varieties have not been compared on a similar basis, as it has been evident for some years that such types have no place on dark soils. Supporting evidence of this conclusion is given in a comparison of yields of early and of late varieties on dark soils in 1932 with those obtained on dark soils in 1934. In 1934 nitrogen reached very high levels during the prolonged heat and drouth, and the tomato crop was virtually a failure in central and northern Illinois owing to blossom drop followed by excessive vine growth. In 1932, temperatures and rainfall were normal. The yields are averages of four replications, the late and early varieties having been paired in the field.

		Acre-yields of U.S. No. 1 and U.S. No. 2 tomatoes on dark soils	
Variety	*Type*	*1932*	*1934*
		tons	*tons*
Prairiana	second early	8.80	10.05
Marglobe (check)	late	10.36	4.44
Early Baltimore	second early	9.39	7.57
Marglobe (check)	late	9.09	4.30

The yields of Marglobe in 1934 were less than half those of 1932, but the second-early types, Prairiana and Early Baltimore, were not so much affected; in fact Prairiana, which has been bred for drouth resistance, actually yielded more in 1934. Since Marglobe is fairly representative of the late-maturing types, the radical change from late to second-early varieties, which has been made in Illinois since 1934, is apparently well justified.

General Rules for Choosing Variety to Fit the Soil.—Thus in adapting varieties to soil type the following general rules may be used as guides:

1. For dark soils, and light-colored soils high in fertility use only second-early varieties.

2. For light-colored soils low in fertility use only the larger-vined, later varieties.

On eroded prairie silt loams, yellow, yellow-gray and reddish-yellow silt loams the earlier types with their inherently restricted vine growth will grow normally if the soil is not deficient in nutrients and organic matter. When fertility is low, the late-maturing types are preferable in southern and probably in central Illinois. In northern Illinois second-early types, like J.T.D., which has a fairly large vine, are being used. In parts of southwestern Illinois, Rutgers is being used on such soils.

The deep loess soils along the larger rivers, as well as some of the better drained alluvial soils, are suitable for tomatoes, but the varietal preference for them is not known. Since 1934 the trend on these soils has been toward the second-early types even in southern Illinois. Experience of the growers has been responsible for this change.

South of the dark-soil belt in Illinois excessive vine growth of tomatoes is not common, because of the generally lower fertility of the soil. Therefore it is quite probable that varieties need not be selected so carefully there on the basis of adaptability to soil types.

FERTILITY PRACTICES FOR TOMATOES[a]

As applications of quickly available commercial fertilizers may reduce yields instead of increasing them on certain soil types and under certain conditions, the reasons for which are not understood, it is impossible at present to make general recommendations for the use of them. In general, unless a grower has convincing evidence that the use of commercial fertilizers on his soil will be profitable, he should depend mainly on the Illinois system of permanent fertility as the first step in successful tomato production.

[a]The use of various kinds of plant nutrients diluted in water and applied at transplanting is discussed on page 26.

The *Illinois system of permanent fertility* means that soil fertility should be built up by means of liming and the use of manure and legumes in the crop rotation. Rock phosphate is needed on many Illinois soils and on many potash is required in addition. All these amendments are necessary in order to supply the minimum requirements of most crops. However, vegetables grown on an intensive scale may require what is known as a "luxury consumption" of plant nutrients in order to give the maximum yields. "Luxury consumption" simply means that if more than the minimum plant-food requirements are available, the remaining portion becomes a luxury for the plants. Vegetable growers often find it profitable to feed their crops large quantities of nutrients, and the aim of most vegetable fertilizer experiments is to show the grower how he can obtain the maximum yields at the lowest cost per unit.

Fertilizing of soils for tomatoes depends, therefore, on whether a permanent soil-fertility program is being followed or whether the soil is in a depleted condition. If the first is true, the question is whether it is advisable to apply any amendment to the permanent fertility system. If the soil is depleted, the grower wants to know what he can substitute for the permanent system in order to obtain maximum yields.

Manure, Phosphorus Most Important Fertilizing Constituents

Three Illinois experiments throw some light on the above questions. Conducted in southern, central, and northern Illinois, respectively, they show remarkable uniformity in results and indicate that without doubt the most important material needed in growing tomatoes is manure. The value of adding some form of phosphorus is also indicated in each of the tests. Cover crops plowed under just before planting did not seem to be an adequate substitute for manure.

Manure and phosphorus are, of course, essential parts of a permanent soil-fertility program. A tomato grower following this program will probably find it advisable to apply the manure directly to the tomatoes rather than earlier in the crop program. If he has no definite fertility program, he should apply ample quantities of manure supplemented with phosphorus.

A brief summary of each of the Illinois tests is given below.

Tests in Southern Illinois.—In this early experiment by Lloyd[8*] on yellow silt loam at Anna, Illinois, the six-year summary definitely shows that manure was the most important soil amendment in tomato production:

	Flats per acre	*Pounds per acre*
Check, no treatment	337.5	6,075
Manure	541.5	9,747
Manure, limestone	610.0	10,980
Manure, limestone, bone meal	642.8	11,570

The reader will perceive that yields kept on increasing the more closely the permanent system of fertility was approached. When a cover crop of rye and vetch was plowed under in addition to the manure, limestone, and bone meal, no further increase in yield was noted. However, when the cover crop was *substituted* for the manure in this treatment, the yields were very little more than the check.

Tests in Central Illinois.—Further tests by Lloyd[9*] on dark silt loam of the prairie type at Urbana gave very similar results to those at Anna, as the following six-year averages in yields of marketable tomatoes show:

	Pounds per acre
Check, no treatment	17,375
Manure	23,224
Manure, limestone	24,922
Manure, limestone, bone meal	25,379
Manure, limestone, bone meal, potash	25,905

Potash, it is obvious, was not needed in this experiment. Cover crops also reduced the yields of tomatoes in all the combinations in which they were tried.

Tests in Northern Illinois.—Experiments by Lloyd and Lewis[11*] on dark silt loam of the prairie type at Des Plaines, in Cook county, completed in 1932, are the most comprehensive fertility tests made with tomatoes thus far in Illinois. The average yields of marketable tomatoes per acre, and the acre-value of the increase less the fertilizer cost, for the most significant treatments were as follows:

	Yield in pounds per acre	*Increase over adjacent check*	*Value less fertilizer cost*
Manure, 20 tons	43,530	17,020	$102.00
Manure, 10 tons, plus—			
500 pounds 4-8-6	43,760	17,250	114 57
500 pounds 6-8-6	43,250	18,320	120.83
2,000 pounds rock phosphate	40,230	17,090	106.70
800 pounds 16% superphosphate	45,190	22,050	154.31
500 pounds bone meal	37,560	12,370	72.80
500 pounds bone meal, 200 pounds muriate of potash	42,310	18,410	117.58
No manure—			
1,000 pounds 4-8-6	42,460	17,530	127.14

The most profitable treatment was 10 tons of manure plus 800 pounds of superphosphate. Rock phosphate and bone meal were not so effective as superphosphate. Of the nonmanure treatments, the most significant was 1,000 pounds of 4-8-6 per acre.

While 20 tons of manure alone produced about as good yields as the best of the other treatments, Lloyd and Lewis[11*] conclude that it is more profitable to use half as much manure and supplement it with phosphorus.

Methods of Using Manure for Tomatoes

The function of manure in tomato growing is not understood and possibly there is some physical effect separate from the organic matter and the nutrients supplied. So far as is known at present, manure does not seem to supply a deficiency in the minor elements as ordinary central and northern Illinois soils are apparently supplied with all the necessary elements.

In order to determine whether small amounts of manure applied around the plants could be substituted for large broadcast applications, the experiment for which the data are given in Table 3 was started in 1937. The increases in tomato yields obtained from applications of manure in 1938 were considerably greater than in 1937, but this may have been due to the fact that in 1937 the experiment was located on an old alfalfa sod, and in 1938 on a depleted orchard soil.

TABLE 3.—EFFECT OF TREATMENTS WITH WELL-ROTTED MANURE ON ACRE-YIELDS OF U. S. NO. 1 AND NO. 2 TOMATOES: MANURE BROADCAST, SIDE-DRESSED, AND APPLIED UNDER PLANTS, URBANA, 1937 AND 1938
(Averages of 5 replications)

Manure treatments, per acre	Yield of U. S. No. 1 and No. 2			Increase from treatment
	1937	1938	Two-year average	
	tons	*tons*	*tons*	*tons*
Early Baltimore				
No manure	4.1	7.4	5.8	...
10 tons, broadcast	4.2	9.4	6.8	1.0
3 tons, under plants	4.7	9.6	7.2	1.4
3 tons, side-dressed	4.2	9.0	6.6	.8
Illinois Baltimore				
No manure	3.4	8.5	6.0	...
10 tons, broadcast	3.4	9.2	6.3	.3
3 tons, under plants	4.4	10.9	7.6	1.6
3 tons, side-dressed	3.9	9.1	6.5	.5

Note.—In 1937 the experiment was located on a highly variable soil, not all of which was well drained, and which had been in alfalfa for three years. The variation in the soil, and the fact that it had been in alfalfa the preceding three years probably account for the relatively small increase from manure. In addition, 0-16-6 fertilizer was side-dressed on all plots at the rate of 150 pounds per acre.

In 1938 the experiment was conducted on an old orchard soil, well drained, having had no treatments in recent years. A broadcast application of 400 pounds per acre of 20-percent superphosphate was made on all plots before planting.

Manure was broadcast or placed under the hills just before planting. The applications under plants were made by marking out the field, digging a small hole, dropping in manure and covering. Side-dressings were given two to three weeks after setting. The manure was scattered closely around the plant and covered with a cultivator.

The particular feature of interest in this experiment is the fact that small local applications at the rate of 3 tons per acre were at least equal to 10 tons per acre broadcast. Applying the manure *under* the plants was more effective than using it as side-dressings.

The local treatments consisted of one No. 10 can of manure per plant. A No. 10 can is a so-called gallon can, but actually it contains less than a gallon—210 cubic inches compared with 231 per standard gallon.

This experiment should be of particular interest to growers who are short of manure, as indicating the most effective way of using what is available. Fresh manure, however, especially if it contains considerable straw, should not be used under the plants.

Commercial Fertilizers

Specific Recommendations Not Feasible.—Extensive fertilizer tests comparing a large number of fertilizer ratios on tomatoes have not been conducted in Illinois, and it is impossible, therefore, to state whether a specific fertilizer analysis can be successfully substituted for the manure and phosphorus in the permanent fertility program, or would give additional increases in tomato yields if added to them.

Other experiment stations have carried on numerous fertilizer experiments with tomatoes, but since in Illinois commercial fertilizers are known to give highly erratic responses and often cause injuries when used with other crops, it is scarcely feasible to give positive recommendations at the present time. It is true that in northeastern Illinois tomato growers are using rather diverse analyses applied in several different ways. On the basis of experiments with other crops, it is probable that an optimum analysis for tomatoes will range somewhere between two to three parts of phosphoric acid to one of potash except on sands and muck soils deficient in potash. Analyses 0-12-6, 0-16-8, and 0-20-10 are examples of 2:1 ratios, while 0-16-6 and 0-15-5 are 3:1 ratios, or close to it.

Use of Nitrogen Salts.—The question is often raised concerning the addition of commercial nitrogen to tomatoes, especially when it is desired to stimulate growth early in the season. The work of Lloyd and Lewis[11*] in Cook county, Illinois, shows that it is unprofitable to use nitrogen except where phosphorus is also applied. Experimental results in Illinois, especially with sweet corn, show that the use of nitrogen in mixed fertilizers is likely to reduce crop yields. Therefore the grower should be cautious in buying mixed fertilizers containing nitrogen, as tomato yields may be reduced in a similar manner.

No direct evidence is available concerning the effect of top- or side-dressed nitrogen salts on tomatoes. On sweet corn in Illinois side-dressed nitrate of soda is profitable only when used in addition to certain broadcasted mixtures containing phosphorus and potash. Elaborate tests applying several nitrogen salts at various times in the season in addition to a hill-dropped analysis—namely, 100 pounds of 0-16-6 per acre—show that the yields of sweet corn are not increased by means of side-dressed nitrogen salts. In Indiana[21*] extensive tests with field corn show that top and side dressings of various nitrogen salts give highly erratic responses. While none of this evidence bears directly on tomatoes, it is important because it shows that nitrogen salts must be used very cautiously in Illinois, and that fertilizer recommendations which are very satisfactory in eastern states do not necessarily apply in this state.

Soil-Testing as a Basis for Fertilizing.—One of the canning companies in Illinois is undertaking a program of adding fertilizers when soil tests show that deficiencies in available nutrients have developed. Every field must be tested individually at short intervals so that the necessary fertilizer salts are applied when needed. This is a costly and laborious program, but in view of the erratic responses from fertilizers, it seems to be the only rational method of attacking the problem. Where this system is used it will be possible to avoid the crop damage which occurs when fertilizers are applied indiscriminately, especially in periods when moisture is deficient in the soil.

Applying Commercial Fertilizers.—When a grower decides to apply commercial fertilizers, there remains the problem of how much fertilizer to use and the method of application. Recent experimental work seems to indicate that the most efficient manner of application is around the plant. For tomatoes this means applying the fertilizer by hand and covering it with a cultivator. Sowing the fertilizers in strips seems to be less efficient because of the wide spaces between the plants and the necessity of using more fertilizer to attain the same results since the roots cannot utilize all the fertilizer until late in the season, owing to the wider area covered. Broadcast sowing of mixed fertilizers is not recommended for similar reasons.

The amount of fertilizer to apply depends on method of application, distance between plants, and the composition of the fertilizer. Heavy fertilizer applications close to the plant may prove worse than none at all. In a large number of fertilizer experiments with sweet corn, applications heavier than 100 pounds per acre around the hill gave erratic responses. It is doubtful, therefore, whether applications around the tomato plant which are heavier than 200 pounds per acre would be advisable. With tomatoes planted 5 x 5 feet, this amount means that each plant would receive a little more than 2 ounces, obviously a heavy application. If a high-analysis fertilizer such as 0-20-10 is used, probably not more than 150 pounds per acre is needed. Fertilizer salts are extremely toxic to practically all kinds of plants if they come into contact with the roots. The degree of toxicity seems to be related to the solubility of the salts, and since high-analysis fertilizers are the most soluble, extreme care should be used in applying them to avoid contact with the plant. All fertilizer salts should be applied so that they do not come into contact with the plant or its roots. Placing the fertilizer in a ring around the plant and then covering with a cultivator seems to be a good practice.

Special Problem Where Subsoil Is Impervious.—On soils having impervious subsoils, such as Elliott Silt Loam and Clarence Silt Loam, commercial fertilizers should be used only on a limited scale until the grower is certain that he is deriving some benefit. No tomato fertilizer experiments have been conducted on such soil types but numerous sweet-corn experiments have shown that commercial fertilizers stimulate plant growth sometimes to an extraordinary extent and yields are almost always lower than on adjacent untreated areas. Since excessive vine growth in tomatoes must be avoided, fertilizers should be used very cautiously on soil types having impervious subsoils.

SOIL PREPARATION

A well-prepared soil is the first essential for successful tomato growing. In a dry spring it is difficult to secure a good stand of plants even on a well-worked soil, but if the soil is cloddy, plant setting becomes an almost hopeless task.

It is easier to get the soil into good shape with fall plowing than with spring plowing. If crop residues are to be plowed under, fall plowing allows them to decay before spring. Sods other than legumes should also be fall-plowed in order to reduce cutworm injury.

Spring-plowed ground dries out very rapidly even if the physical condition is good, and unless watered heavily the plants are apt to wilt badly when set on such soil. Spring plowing is poor practice where plants are set by machine, as the trash which is turned under has no chance to decay and may interfere with the transplanter. Manure plowed under in the spring decays very slowly if rainfall is deficient and may interfere with the capillary rise of the soil moisture. Plants do not start well in such soils. Plowing under cover crops in the spring is not recommended for Illinois conditions.

Substituting a spring-plowed cover crop for manure, in experiments by Lloyd[8*] in Union county, Illinois, reduced the yields of tomatoes considerably, and the use of a cover crop in addition to manure did not prove to be advisable. In later experiments at Urbana, Illinois, Lloyd[9*] showed that spring-plowed cover crops almost invariably reduce the yields.

On Elliott Silt Loam and on Clarence Silt Loam, both of which have plastic and more or less impervious subsoils, the plowing under of considerable quantities of organic matter, such as sweet clover in the spring, has seriously reduced the yields of sweet corn. There is a possibility that tomatoes may suffer in a like manner. Fall plowing on these soil types seems to be preferred.

Deep plowing is preferable to shallow plowing. It is difficult to set plants deeper than the plow sole even by hand, and with a transplanter it is almost impossible. Deep setting in a dry spring is an absolute necessity.

Roots of transplants must reach moist soil if they are to live. Any practice which increases the moisture-holding capacity of the soil at transplanting time will save the grower a great deal of trouble.

RAISING, HANDLING, AND SETTING PLANTS

In Illinois the growing of tomato plants is usually limited to those grown by truck growers for their own needs. Cannery growers receive plants from the factory, and most of these are southern grown. Until a few years ago there was considerable prejudice against southern-grown tomato plants. These objections were sometimes well merited because poor strains of seed were used and, owing to careless handling and packing, frequently plants arrived at their destination in poor condition.

In recent years the situation has changed considerably and high-quality southern-grown plants are now competing very successfully with home-grown plants. This is especially true where such plants are distributed by canners who, in many instances, supply the seed, contract directly with the growers, and supervise the packing and shipping operations. Many canners are now furnishing only plants which have been certified by state authorities in the south. The usual requirements are that such plants can only be grown from certified seed which has been chemically treated. In addition the plant beds are sprayed and must be free from diseases. Thus southern-grown plants now usually reach the growers in good condition. It is then up to the grower to handle them properly and plant them quickly.

Value of Transplanting

There are many methods of growing plants in common use, and it is commonly believed that transplanting is especially beneficial because better root systems are produced. Loomis[12*] investigated the problem very thoroly and concluded that transplanting in itself is not beneficial. He found that transplanting in the very early seedling stage did not injure the plants particularly, but later transplanting was more or less injurious depending on how well the crop was adapted to withstand root disturbance.

Loomis[12*] observed that transplanting increased the amount of branching in the roots, but this was merely a temporary effect. In fact any previous treatments which the plants may have had were more or less masked by the degree of disturbance which the roots received when they were set in the field. Thus the increased branching would be of little value if most of the roots were broken off in the process of setting the plants in the field.

In one experiment Loomis[12*] showed that tomato plants grown in paper pots gave consistently larger early and larger total yields than plants grown in flats because in the former instance roots were disturbed considerably less when the plants were set in the field. Loomis also showed that plants grown from seed sown directly in the pots were just as good as those transplanted once or twice.

These and similar experiments are of importance to the grower as they show that an early transplanting does no harm but that late transplanting is not advisable because of the root disturbance. Transplanting seems, therefore, to be merely a means of saving space, and the practice of repeated transplanting in order to prevent the plants from becoming spindly is not recommended, even tho a new root system develops just below the surface of the soil every time the plant is reset a little deeper. Such secondary root systems are claimed to be beneficial because the "plant will stand up better and the new roots will develop along the stem."[20*] The experiments of Loomis[12*] show clearly that transplanting has a retarding effect; and under the circumstances it is difficult to see how a secondary root can be especially beneficial since it will develop only when the original root system ceases to function properly.

Hardened and "Frost-Proof" Plants

The practice of hardening plants is an old tradition and practically all the older writers regarded well-hardened plants as one of the basic essentials of successful crop production. Modern experimental work, however, indicates that hardening is injurious. A comparison of tender and hardened tomato plants by Crist[3*] showed that the tender plants gave larger yields early in the season, but that as the season progressed the differences between the two became progressively smaller, until at the end the two lots gave practically identical total yields. Hardening checked the growth of the tomato plants, as shown by the smaller early yields, and considerable time was required before they recovered.

Well-hardened plants are usually believed to be more resistant to cold and are often advertised as "frost-proof." Experiments by Rosa[14*] showed that any treatment which materially checks plant growth also increases resistance to cold. In hardy species like cabbage and related plants hardiness increases in proportion to the degree in which growth is checked, but in tender species, such as tomatoes, hardening increased the cold resistance to such a slight degree that for practical purposes there was no apparent difference.

Care of Plants Before Transplanting to the Field

Tomato plants should not be allowed to wilt before or during transplanting. If they cannot be set at once upon receipt by the grower, the bundles should be loosened and the roots dipped into a puddled solution of liquid mud. The mud coats the roots and prevents them from drying out rapidly. The tops must not be wetted. The puddled plants may be repacked rather loosely in boxes or in baskets which are covered with dampened burlap bags. A good storage space will be a cool, damp cellar or basement.

When plants are to be held longer than 24 hours, "heeling in" or trenching has usually been considered advisable, but according to recent experimental work this practice should be discouraged, for the yields were adversely affected by lengthening the holding period.

Plants must not be exposed to the sun any more than necessary during setting. Wilted plants are difficult to set and the percentage surviving is very low.

Date of Setting in the Field

Ordinarily the best time to set tomato plants will be the earliest date when they will stand a reasonable chance of escaping a late spring frost. In Illinois this time varies from April 25 to May 30, depending on the section of the state.

In a number of experiments on time of planting tomatoes in eastern states the highest yields were usually obtained from the earliest plantings. This proved to be true also in an experiment in Illinois in 1937 (Table 4), where despite the fact that the earliest setting of plants was made during a protracted cool, rainy period, the earliest (May 12)

TABLE 4.—TIME OF PLANTING IN RELATION TO ACRE-YIELD AND TIME OF MATURITY OF U. S. NO. 1 AND NO. 2 TOMATOES, URBANA, 1937
(Averages of 5 replications)

Date planted	Yield	Yield of checks planted May 24	Increase over check	Percentage of total crop picked by September 1
Early Baltimore	*tons*	*tons*	*tons*	
May 12	10.15	9.91	.24	82.3
May 24 (checks)	.....	.....	.....	69.4
June 5	4.54	10.18	−5.64	22.1
June 19	1.19	9.49	−8.30	7.1
June 30	.31	8.34	−8.03	12.8
July 12	.30	10.00	−9.70	14.3
Illinois Baltimore				
May 12	10.38	10.12	.26	67.8
May 24 (checks)	.....	.....	.....	42.0
June 5	4.50	10.14	−5.64	22.3
June 19	1.01	10.37	−9.36	11.6
June 30	.31	10.05	−9.74	8.2
July 12	.28	10.67	−10.39	6.2

Note.—Every fifth plot was a check plot.

settings gave the highest yields. Yields from all plantings after May 24 were very much lower, even with the earlier-maturing variety, Early Baltimore, and despite the very favorable growing conditions in 1937.

The effect of early planting on maturity is also shown in Table 4. From the midseason variety Illinois Baltimore the percent of the total crop picked before September 1 decreased as the time of planting was delayed; but from the second-early type, Early Baltimore, a slightly higher proportion of the total crop was picked before September 1 from the plantings of June 30 and July 12 than from the planting of June 19, probably because conditions for setting were a little more favorable when the later plantings bloomed.

Nevertheless late planting should certainly be avoided whenever possible, because in a drouth season the late settings would come into bloom under the most unfavorable conditions of heat and dryness and the differences might be even more pronounced than those shown in Table 4.

Methods of Field Setting

Tomatoes are set in the field either by hand or by machine. Each system has certain advantages and neither is capable of entirely replacing the other. The one best adapted for each grower will depend upon a number of factors and, therefore, no general recommendations can be given.

Mechanical Setters.—Mechanical plant setters are economical to use where a large acreage is to be set. The rows must be long, as frequent turning may require more time than the actual setting and in addition it is impossible to set close to a fence row. The field must be fairly level, as plant setters tend to slide downhill and it is difficult to follow a straight row. The ground should be well prepared and free from clods and trash. As the shoe of the setter will not go deeper than the plow sole, deep plowing is essential. The setter will plant in check rows, but not very accurately, and many growers do not even bother to try to check. The machine has the great advantage of watering the plants and, therefore, the percentage of survival is likely to be higher than in hand setting without watering.

The transplanting machine is limited to use with one type of plant—namely, the seedling which has practically no soil adhering to the roots.

Hand Setting.—Where the grower is setting potted or blocked plants, both of which require careful handling in order to preserve the soil around the roots, hand methods are advisable. Hand setting is also preferable where the plants are longer than 12 inches. Even with a deep shoe, such as is furnished on special order with certain planters, it is impossible to set deeper than 5 or 6 inches. A deep shoe increases the draft materially, and even a heavy team will have difficulty in pulling the load.

There are numerous variations in the practice of hand setting. Small seedlings are often set with a regular dibber, or with a dibber made from a "D" shovel handle sharpened at one end. Potted or blocked plants are set with a spade or a trowel. Occasionally the grower will plow furrows, but this is a practice which is not recommended because of the loss of moisture from the soil.

Setting in Furrows.—In dry years or when high winds are persistent, plants are sometimes set in the bottoms of holes dug with a spade. The holes are merely deep enough so that the top of the plant is level with the surface of the soil. This practice seems to give a great deal of protection and was used successfully in the dry springs of 1934 and 1936. But in a cool wet spring trenching of any kind is not likely to be profitable. In an experiment at Urbana in 1937 with seedling plants, transplanted once but with no dirt adhering, the setting of the plants in furrows reduced the yields by 1.5 to 2.2 tons per acre (Table 5). Even when each plant was mulched with one gallon of rotten manure the yields were still .6 to .7 ton below those obtained from the check plots planted level without manure.

TABLE 5.—ACRE-YIELDS OF TOMATOES AS AFFECTED BY SETTING PLANTS IN FURROWS, IN A COOL WET SPRING, URBANA, 1937
(Averages of 5 replications)

Type of planting, and soil treatment	Yield of U. S. No. 1 and No. 2	Decrease due to furrows
Early Baltimore	*tons*	*tons*
In furrows	2.7	1.5
On level ground	4.2	...
In furrows, with manure	3.2	.6
On level, no manure[a]	3.8	...
Illinois Baltimore		
In furrows	1.4	2.2
On level ground	3.6	...
In furrows, with manure	2.6	.7
On level, no manure[a]	3.3	...

[a]No direct comparisons could be made with plots planted on level ground and treated with manure.

Use of Water and Nutrient Solutions in Transplanting

Under average conditions in Illinois watering is necessary at time of planting, especially when the plants have no soil adhering to the roots and are set by hand. The plants may be watered as soon as they are set, but this is wasteful, as much of the water runs along the surface instead of seeping in. Some growers scoop out a little dirt from around the plants, making a depression to retain the water. Later dry soil is hoed around the plant. Other growers scoop out holes with a hoe and fill them with water just before the plants are set. This seems to be the most efficient practice as the roots are then set in mud and, under ordinary conditions, not more than a half pint of water is required for each plant.

The purpose of watering is to permit the plants to establish themselves without the check which follows severe wilting. Even plants that are watered, however, ordinarily seem to make almost no growth for several weeks after setting, and various attempts have been made to speed up growth by adding fertilizer salts to the water. Nitrate of soda has been tried, but the results have not been encouraging.

So far the most promising method of preventing this check to growth, especially on soils low in available phosphorus, is the watering of the plants at setting with a solution of 3 pounds of diammonium phosphate in 50 gallons of water. Greater concentration may cause stunting, but where the given dilution was tried in northern Indiana, the plants started more quickly, set fruits earlier, and gave better yields than where water alone was used.[1, 2*] The cost of this treatment is about $1 an acre when ½ pint of solution per plant is used.

Treatments with 75-percent commercial phosphoric acid, monoammonium phosphate, hemiammonium phosphate, and glucose phosphate were better than plain water but not so good as diammonium phosphate.

Tests at the Cook county branch experiment station in 1938 on soil with ample available phosphorus failed to show any advantages for nutrients added to the water used in transplanting.

Conditions for Setting

Plants should not be set when the ground is either too wet or too dry. "Mudding in" tomato plants may seem to be desirable because no watering is necessary and the percentage of survival is high. The objections are that the soil is badly puddled, especially around the roots and, while the plant may survive, it may be retarded as the roots will find it difficult to grow in a hard ball of packed soil which is too close to the plant to be broken up with the cultivator.

It is very difficult indeed to set plants in extremely hot weather or when heavy winds are blowing. Under such conditions the percentage of plants lost is very high and the survivors may suffer a severe check. If setting in dry or windy weather is necessary, it is advisable to do the work during the cool part of the day, either early in the morning before ten o'clock or late in the afternoon. Planting at night will prove to be profitable when conditions are adverse. The principle to be followed in such cases is quite simple. If wilting can be delayed for 12 hours, the plant will ordinarily survive.

Resetting, that is replacing dead plants, is often neglected by the grower, who thereby is likely to sacrifice part of his yield. If the loss does not exceed 5 percent, the value of resetting is questionable because so small a loss will probably cause no noticeable decrease in yield. If more than 5 percent of the plants are missing, the plants should be reset as soon as possible. Since it is difficult to water such plants unless the water is carried around the field by hand, a favorable time, such as a cloudy day, should be chosen for resetting and only good plants used.

In the event losses are as high as 40 percent or more and the grower has used a machine, the proper procedure becomes a matter of judgment. Sometimes it will be expedient to disk up the whole field and plant over again rather than to reset the missing plants by hand. The course to follow will depend on the weather, the time of the year, and the comparative speed of the alternatives.

Planting Distances

Planting distances for tomatoes in Illinois have varied tremendously in the past, but recent experience with the newer varieties indicates that the plants should be set far enough apart for the surface allotted to each to be from 12 to 25 square feet. Three factors seem to be involved in determining the planting rate: the variety, the soil, and the season.

The smaller-vined types, such as John Baer, Pritchard, and Early Baltimore, need less space than late-maturing large-vined types, such as the late Baltimores, Illinois Pride, and Stone. There can be no one best planting distance for each variety, because soil differences seem to be the dominant factor determining how far apart the plants should be. On fertile soils, especially the dark-colored prairie silt loams, the earlier varieties develop a vigorous vine growth and must consequently be planted *farther apart* than on poor soils where vine growth is restricted. Thus on a highly fertile soil 5 x 5 feet would be just about the right distance for John Baer, Pritchard, and Early Baltimore, while on a poor soil these varieties might be advantageously planted 3 x 3 feet.

Competition and mutual protection must be considered in determining planting distances. If a crop is planted too closely, competition is excessive and the yield suffers. If planted too far apart, the plants do not protect each other and are excessively exposed to the weather. Yield again suffers. In order to obtain maximum yields, it is obvious that the planting distance must be very nicely adjusted; but since the three factors of variety, soil, and season are involved, it is possible only to strike an average.

Two late-maturing tomato varieties planted on a depleted dark silt loam fertilized with 500 pounds of 0-16-6 per acre, at Normal, Illinois, in 1931, show how yields were reduced by planting too far apart in a season when excessive vine growth was not a factor. Entirely different results would most likely be obtained during a season when vines grow excessively large.

Planting distance, feet	*Tons per acre* Marglobe	*Greater Baltimore*
5 x 4	20.34	13.90
5 x 5	18.32	13.62
5 x 6	25.23	(no data)
6 x 6	9.45	7.46
6 x 7	9.08	8.41

It is obvious that these tomatoes required between 20 (4 x 5) and 30 (5 x 6) square feet per plant in 1931, but it is impossible to generalize from these limited data. The experiment was not continued.

Since seasonal variations in temperature and rainfall affect vine growth, they determine to a considerable extent the optimum planting distance. When rainfall is well distributed, the earlier varieties with normally restricted vines make a vigorous growth, and the late-maturing types do not develop excessively large vines. Wider planting would thus be indicated for the earlier varieties and closer planting for the late-maturing types under these conditions. In a dry season when nitrogen may accumulate in the soil, the reverse might be true because the earlier types may develop abnormally small vines and the late varieties abnormally large ones, depending on the soil.

Because of the number and diversity of the factors involved, strictly definite planting distances cannot be recommended, and the following suggestions are submitted only as a general guide:

Varietal group	*Vine type*	*Planting distances on—* *Yellowish to grayish timber soils*	*Dark prairie types*	*Alluvial types*
Early				
Earliana	Small	3′ x 3′	4′ x 4′	4′ x 4′
Second early				
John Baer, Early Baltimore, J. T. D., Prairiana	Medium	4′ x 4′	4′ x 5′	4′ x 5′
Pritchard	Bushy	3½′ x 3½′	4′ x 5′	4′ x 4′
Late				
Greater Baltimore, Illinois Baltimore, Indiana Baltimore, Illinois Pride	Large	4′ x 5′	5′ x 5′ to 5′ x 6′	5′ x 5′

Direct Seeding in the Field

In the last two years there has been a widespread revival of interest in growing tomatoes directly from seed sown in the field. In 1938, a considerable acreage was so planted in Ohio and Illinois and the growers were well satisfied with the results.

The practice consists of sowing the seed in the field in rows 4 to 5 feet apart with a gang of four hand seeders pulled by a tractor at a rate of about 20 ounces of seed per acre as soon after April 15 as possible. The plants are allowed to grow until about 4 to 6 inches tall, when they are thinned by hoeing or by cross cultivation. If more than one plant remains at the cross mark, hand thinning is required.

Plants grown in this way seem to be much more frost resistant than transplanted plants. Reports show that heavy May frosts in Ohio and Illinois killed transplants, but injured none of the direct field seedings.

1938 Illinois Experiments.—The Illinois Station started experiments in field planting in 1938. The field was cross-marked 4 x 6 feet, and the seed sown May 6 with a hand corn planter at the cross marks, about 20 per hill. Plants were thinned when 2½ inches high. Plant protectors, where used, were placed the same day the seed was sown. Seed for the transplanted plants was sown in the greenhouse April 9, and the plants when 1 inch high were transplanted to flats which were removed to cold frames. The plants were set in the field May 20.

The results for 1938 are given in Table 6. The direct-seeded plots failed to yield as well as the transplanted. Maturity was delayed by direct seeding much less with the second-early variety, Early Baltimore, than with the late type, Illinois Baltimore. Apparently, direct seeding is more successful with earlier varieties than with late ones. There were no consistent differences in the percentages of U. S. No. 1's.

Plant protectors were of no advantage in this experiment; in fact they were disadvantageous. The yields were slightly reduced owing to their use, apparently because the seedlings became spindly under the protectors and were in poor condition when the protectors were removed.

TABLE 6.—ACRE-YIELD AND TIME OF MATURITY OF FIELD-SEEDED TOMATOES WITH AND WITHOUT PLANT PROTECTORS, AND OF TRANSPLANTED COLD-FRAME PLANTS, URBANA, 1938
(Averages of 5 replications)

Variety and treatment	Yield of U. S. No. 1 and No. 2	Proportion of total crop picked by Sept. 3
Early Baltimore	*tons*	*perct.*
Direct seeding, no protectors	9.235	60.6
Direct seeding, protectors used	8.893	56.9
Transplanted	11.892	72.0
Illinois Baltimore		
Direct seeding, no protectors	8.127	42.3
Direct seeding, protectors used	7.763	43.7
Transplanted	12.353	73.9

Direct field seeding has considerable promise, but until more definite proof of its value becomes available, the grower is cautioned not to plunge too heavily. However, the grower may be able to afford a reduced yield because the cost of growing a direct-seeded field is of course considerably less than the cost when the plants are transplanted.

Field Demonstrations by Canning Company and Growers.—The following statements regarding direct seeding demonstrations in Cook county by the Campbell Soup Company and cooperating growers, in 1938, have been furnished thru the courtesy of E. W. Montell of that company:

"The seed is sown in the field the latter part of March as soon as the soil is in condition to work, but it may be sown as late as April 25th, with a double row garden drill hooked behind a corn planter with a fertilizer attachment. A perfect seed bed is essential as the seed must be sown shallow and for that reason any loss of moisture caused by poorly worked ground will prevent germination. Flow of seed is regulated to drop a seed every 2½″ and this requires 1¼ to 1¾ pounds per acre, depending upon the width of the rows. Seeder should be set to cover the seed ¼″ to ½″ deep. Mix a few radish seeds with the tomato seed so as to determine where the rows will be and this will permit cultivation before tomato seed germinates. The furrow openers on the corn planter loosen and pulverize the soil ahead of the seeder and 125 lbs. of fertilizer to the acre is sown [by the corn planter] ½″ below the seed. Shortly after seed germination, it is sometimes necessary to break the crust. This is done with a series of notched discs approximately 6″ in diameter. These units of discs can be mounted on a beet cultivator and the crust can be broken on two rows at a time. Regular single row, hand operated, crust breakers can be purchased already assembled.

"Seed should be above the ground by May 1st to 10th and plants should average 6″ by May 20th to 25th. When plants reach this size they are blocked out to the desired distance. The distance between the plants should not exceed 4′ and is generally 3½′. Blocking time is two (2) acres per man per day. If the stand is regular, considerable of the blocking can be done by driving a cultivator across the rows at the width desired.

"After blocking an additional application of fertilizer is side-dressed with a corn cultivator or beet cultivator.

"Harvest should begin on seeded fields as quickly as fields of transplants and hit the peak at approximately the same time. Vines on direct seeded fields hold longer and are freer of blight.

"Following is a comparative yield record of seeded fields and the shipping-station average in Cook County, Illinois: seeded fields, 8.24 tons per acre; shipping-station average, 5.41 tons per acre."

Answers, from cooperating growers, to a questionnaire sent out by Campbell Soup Company on the results obtained in these demonstrations of direct seeding are given in Table 7.

TABLE 7.—ANSWERS TO QUESTIONNAIRE ON DIRECT FIELD SEEDING OF TOMATOES, SENT BY CAMPBELL SOUP COMPANY TO COOPERATING GROWERS, 1938

(Each grower grew, for comparison, both direct-seeded and transplanted tomatoes.)

Grower	Date of seeding tomatoes	Date thinned	Did direct-seeded plants begin bearing as soon as transplants?	Did the direct-seeded plants blight as readily as transplants?	Did you pick as many tomatoes from the direct-seeded plants as from an equal number of transplants?	Remarks
A	April 19	June 10	No	No	No	If seeded April 1 will compare favorably with transplants.
B	April 15	June 5	No	No	Yes	No remarks.
C	April 20	June 5	No	No	No	Would have picked as many if late rains had not caused tomatoes to rot.
D	March 28	No record	....	....	....	Rain washed seed away.
E	April 16	June 1	Yes	No	Yes	No remarks.
F	March 21	May 25	Yes	No	Yes	Direct-seeded tomatoes yielded better and were of better quality.
G	April 1	No record	....	....	....	Failed to get a stand.
H	April 19	No record	Not quite	Yes	Equal	Hard frost May 11 and 12 did not affect direct-seeded plants.
I	April 20	May 27	No	No difference	No	Direct-seeded about two weeks later.
Summary	....	....	5 no, 2 yes	5 no, 1 yes 1 the same	3 no, 3 yes 1 the same	

Note.—Under "Remarks" all except one grower indicated that they believe direct-seeded tomatoes would yield as well as transplants, or better, if (1) the direct-seeded tomatoes are planted early enough for them to mature as early as the transplants; or (2) if weather conditions later in the season, when the later-maturing direct-seedings are picked, are as favorable as during the earlier period when the transplants are harvested.

CULTIVATION

Depth and Frequency.—Under Illinois conditions the number of cultivations which are required to control weeds will usually be sufficient to keep the soil in a good state of tilth. Shallow cultivation is preferable to deep cultivation. Until very recently most publications recommended "frequent shallow cultivation" without questioning its value or its necessity. In recent years the whole question of cultivation has been studied and the general conclusion has been reached that cultivation is essentially a weed-killing operation and the maintenance of a soil mulch is of comparatively little importance.

Results of Experiments.—Thompson[17*] in experiments in New York investigated the value of soil mulch. In one series of experiments a soil mulch was maintained by cultivating once a week with a wheel hoe and in another series there was no soil mulch and the soil surface was scraped with a hand hoe only when weeds appeared. The results of six years' work with tomatoes show that the two methods of cultivation gave almost identical yields. Soil mulch is supposed to conserve moisture in the soil, but in these experiments the soil moisture was higher in the cultivated (soil mulch) plots only about two-thirds of the time.

The only work on cultivation in Illinois is on field corn, but certain principles which most likely apply to other crops as well were established therein. Morrow and Hunt of Illinois began cultivation experiments as early as 1888 and found there was no advantage in cultivating more frequently than is necessary to destroy weeds and, further, that shallow was preferable to deep cultivation. As this was so contrary to popular belief the experiments were repeated by Wimer and Harland,[22*] and they also found that the highest yields were obtained when no cultivation was given beyond keeping down the weeds by means of scraping with a hoe. Even shallow cultivation was not as good as scraping with a hoe. They also found that in a dry season less and not more cultivation is preferable. Wimer and Harland[22*] conclude that cultivation should be as shallow as possible and that its function is simply to destroy weeds. On soils which crack badly cultivation may be necessary to fill in the cracks. They state that a dry crust on top of the soil is probably just as effective in reducing evaporation of soil moisture as is a granular mulch and if such a dry top layer forms promptly after a rain, cultivation is not needed.

Thompson[17*] found that cultivation often results in loss of moisture during critical periods, and at other times it conserves moisture when less moisture would be desirable. Cultivation is not advisable after a light rain because practically all the moisture may be lost before it has time to penetrate the soil.

Tendency to Overdo.—The grower must not interpret the results of these experiments too literally. Cultivation is necessary for all crops planted in rows. In truck growing, however, there seems to be a tendency to overdo cultivation in the belief that in some manner the crop is receiving benefits. Cultivation, no matter how shallow, disturbs the roots and such disturbance retards the plant. It is the soil which is being cultivated—not the crop—and any benefit which the crop derives will be by means of improved soil conditions, and this benefit will have to be greater than the injury the crop receives because of root disturbance.

STRAW MULCH

Because potatoes are often successfully grown in Illinois under a straw mulch, tomato growers have concluded that mulching would also be beneficial for tomatoes. The thought has been that by conserving soil moisture and reducing soil temperatures the mulch would cause the tomatoes to set much better, especially in a hot dry season.

The use of straw mulch for tomatoes is being studied by the Illinois Station and the results of two years of work are not consistent. In 1937, yields were reduced by the use of straw mulch, but in 1938 they were greatly increased (Table 8). The depressing effect of straw mulch on the 1937 yields was probably due to the fact that the experiment was located on a heavy black clay loam having slow drainage. The mulched plants grew very slowly. In addition the late planting date in 1937 (June 10) delayed maturity very materially.

The 1938 tests were located on a well-drained but depleted orchard soil low in phosphorus. The increases in yields resulting from the use of straw mulch were very large indeed. Mulching of tomatoes thus shows considerable promise, but well-drained soils are needed and early planting is advisable because mulching delays maturity. The retarding effect on maturity is shown by the percentages of the total crop picked by early September (Table 8).

Mulched tomatoes are much slower growing than cultivated plants, and during the greater part of the season they are smaller than those which are cultivated. Leaves of mulched plants frequently have a persistent yellowish-green color owing to lack of nitrogen, a condition which does not appear in the cultivated plants located nearby. When the leaves of mulched plants turn yellowish, it will probably pay to add nitrogen salts, altho none was added in these tests.

TABLE 8.—EFFECT OF STRAW MULCHING ON ACRE-YIELDS, QUALITY, AND TIME OF MATURITY OF TOMATOES, URBANA, 1937 AND 1938
(Averages of 5 replications)

Treatment and variety	Total yield U. S. No. 1 and No. 2	Increase due to mulch	Proportion U. S. No. 1	Proportion of total crop picked by Sept. 2[a]
1937				
	tons	*tons*	*perct.*	*perct.*
Early Baltimore				
Straw mulch	3.61	−.55	17.40	9.96
Cultivated	4.16	....	16.73	26.95
Illinois Baltimore				
Straw mulch	1.96	−1.69	12.40	8.56
Cultivated	3.65	....	19.87	22.14
1938				
Early Baltimore				
Straw mulch	15.39	7.96	31.69	46.8
Cultivated	7.43	....	16.28	60.7
Illinois Baltimore				
Straw mulch	15.12	6.61	24.15	58.0
Cultivated	8.51	....	10.79	73.8

Note.—In 1937 tomatoes were planted June 10, 2 cultivations given to all plots, followed by a hill application of 150 pounds 0-16-6 per acre. Straw mulch was applied 6 inches deep July 3.

In 1938 tomatoes were set May 26, 1 cultivation given and straw mulch applied 6 inches deep June 9. All plots received 400 pounds 0-16-6 fertilizer broadcast before planting.

[a]By September 6 in 1938.

Mulching in 1938 gave a large increase in the percentage of U. S. No. 1 fruits, as shown by Table 8. There was much less cracking and the color of the fruits was superior to those of cultivated plants.

IRRIGATION

Following the severe drouths in the Middle West in 1934 and 1936, growers have evinced great interest in supplementary irrigation. The subject is not a new one, and there are numerous installations of overhead sprinklers in Illinois; but the cost has been too high for the average grower. Present interest centers mainly on cheap methods of surface irrigation, based on western practices. The relative value of the different systems will not be discussed here, but rather the beneficial results from actual experiments.

Any system of irrigation depends on an abundant and cheap supply of water. Shallow wells are possible in some sections, but in Illinois irrigation will depend largely on surface supplies from streams and ponds. Installations which have been inspected consist primarily of a centrifugal pump powered by a tractor, or an old automobile engine.

The lift is usually very short and the water is pumped thru a 2- to 4-inch pipe to the field to be irrigated.

The Campbell Soup Company of Chicago in 1937 investigated the possibilities of irrigating tomatoes, and the results of those tests made in cooperation with one of their growers are reported here. The farm was located on the DuPage river and the pump was stationed on the bank of the river, giving a 12-foot suction lift. The 4-inch centrifugal pump was driven by a belt from a farm tractor. The only other equipment consisted of 600 feet of round smooth galvanized iron down-spouting and 20 feet of 4-inch discharge hose. At the end of this hose a 10-foot length of down-spouting was soldered into the hose connection. The water was carried to different parts of the field by means of the down-spouting and a number of elbows.

Since the field was not level, the water had to be piped to the higher spots and then carried between the rows by means of furrows and shallow trenches. The highest spot in the field was 50 feet above the river level, but no difficulty was encountered in raising the water to that level.

Rainfall during the growing season of 1937 was fairly well distributed during June and July and late in August, so that only one irrigation was needed during the early part of August. The effect on yield is given in Table 9. The gain for the single irrigation was 3.2 tons per acre, having a value of $51.20. Four acres were irrigated once, the equipment being used a total of 19 hours. The costs involved are listed below.

Labor and fuel		
Labor, 25 man hours @ 30 cents		$ 7.50
Fuel, 19 gals. distillate @ 7 cents per gallon		1.33
Oil, 2 gals. @ $1.00 per gallon		2.00
Total labor and fuel cost		$10.83
Equipment cost		
Second-hand centrifugal pump	$75	
600 feet of down-spouting	72	
Suction and discharge hose, second-hand	30	
Foot valve	4	
Nipples	3	
Total equipment cost	$184	
Apportioned equipment cost, 20% of $184		56.80
Total cost of irrigating 4 acres		$67.63
Crop gain per acre (*Table 8*)		$51.20
Cost of irrigating per acre		16.91
Net gain per acre		$34.29

Thus even in one of the best seasons for tomatoes Illinois has ever had, irrigating was profitable. In a dry season the differences would no

TABLE 9.—EFFECT OF ONE SURFACE IRRIGATION ON ACRE-YIELDS OF MARKETABLE TOMATOES GROWN NEAR DUPAGE RIVER, 1937

Date of picking	Baskets of tomatoes per acre		
	Irrigated once	Not irrigated	Gain from irrigation
August 18	15	9	6
August 28	48	31	17
September 2	82	48	34
September 8	165	95	70
September 11	49	29	20
September 17	101	59	42
September 23	30	20	10
October 4	31	20	11
Total baskets[a]	521	311	210
Total tons	8.1	4.9	3.2
Value at $16 per ton	$129.60	$78.40	$51.20

[a]A basket of tomatoes weighs about 32 pounds. Returns have been calculated on basis of total marketable tomatoes at an average price of $16 a ton.

doubt be considerably greater. The irrigated tomatoes had increased vigor and the fruits appeared to be of better quality. If a grading record had been kept, the above gain of $34.29 an acre would probably have been larger.

STAKING AND PRUNING

Not Generally Recommended.—Staking and pruning are practices not recommended for Illinois conditions unless the grower has, by means of trial, demonstrated that under his particular conditions these practices pay. Experimental results differ slightly but show no consistent advantages for staking and pruning to offset the tremendously increased costs of growing.

Tomatoes are staked primarily to keep the fruit from contact with the soil, thus reducing the danger of decay, but staking has never been widely adopted in Illinois. It is claimed that staking increases the total yield per acre, the percentage of fancy tomatoes, and the size of fruits and earliness of maturity. However, there is considerable uncertainty whether the Illinois grower will derive any particular advantage from staking. Staking and pruning are known to increase blossom end rot, and recent experimental work indicates that they also cause an increase in cracking. In Illinois it is always dangerous to remove any part of the foliage because exposure of the fruits to the sun usually prevents them from developing a bright color, and if the weather becomes hot, sun scald usually appears.

Results of Pruning Experiments.—The experimental work on pruning does not lend much encouragement to the grower to follow this practice. In experiments in New York state Thompson[18*] found that only when the number of pruned plants per acre was more than double the number of unpruned ones did the pruned plants produce as large a yield per acre. These results are in accord with the work in many other states, including that of Lloyd and Brooks[10*] conducted in Union county, Illinois, and at Urbana. Working in Arkansas, Watts[19*] found that total yields were markedly and consistently reduced by pruning in proportion to the severity of the pruning. Pruning did not increase the early yield, and in fact actually reduced the total acre-yields, in spite of the fact that there was a decrease in sun scalding on trained plants. He concludes that "labor spent in heavy pruning serves no good cause, and may result in reduced yields." Thompson[18*] found that pruning gave a slight increase in the percentage of first-grade fruits, but this was counterbalanced by increased cracking, blossom-end rot, and sun scalding on the pruned vines. However, pruned plants gave larger early yields.

Practices of Growers.—Methods of staking tomatoes vary from simply holding the branches off the ground by means of barrel hoops nailed to stakes, to severe pruning and tying to poles or trellises.

One northern-Illinois grower who ties his plants to trellises, plants in double rows 18 inches apart with the pairs of rows 36 inches apart. The rows run north and south in order to provide maximum shading. The plants are set 20 inches apart in the rows and are staggered in the double rows. The trellises are put up when the plants are about 12 inches tall. Steel fence posts are driven about 50 feet apart in the middles of the 18-inch spaces, and a wire is stretched from post to post 3 feet from the ground. A plaster lath is driven 3 to 4 inches into the ground on the north side of each plant and tied to the wire. The result is a braced trellis that will hold a heavy crop. The rows should be short where this type of trellis is used, for the trellis makes it impossible to walk across the field.

Some tomato growers use stakes similar to bean poles, generally about 6 feet long, and driven into the ground beside each plant. Where this method is used the plants are generally set in single rows 18 to 24 inches apart in the row and 3 feet between rows.

With either method the plants must be tied to the laths or the poles as soon as these are set. Soft manila or jute twine (post-office grade) is excellent for the purpose. Ties are made at intervals of about 15 inches, and tying must be continued until the plants are headed. When the plants reach the wire or top of the pole they are headed by cutting off the growing tip.

When tomato plants are staked or trellised in this manner they are generally pruned to a single stem, for they are then most simply managed. Pruning begins as soon as the side shoots which start to grow in the axils of the lower leaves become large enough to be pinched off with the fingers. The fruit clusters are not removed, of course, and care should be taken not to remove the growing point.

HARVESTING AND GRADING

Since shipment of tomatoes in the form of fancy packs to distant markets is not now important in Illinois, the problem of harvesting and grading is one of adaptation to local market requirements. Local markets want ripe tomatoes, and therefore harvesting and grading standards for market become almost identical with the requirements of tomato canners. There is probably a tendency for local market tomatoes to be picked slightly greener than cannery tomatoes. The sales value of tomatoes is determined by color, size, and freedom from cracks and other blemishes.

Meeting Color Preferences

Tomato color may be controlled to a considerable extent by the grower. Careful selection of a field that is protected from hot winds and has sufficient fertility to grow proper-sized vines, and attention to correct distance of planting in the field will aid in protecting the fruits so that normal color development is possible.

There is considerable varietal difference in color among tomatoes. The red color in the flesh of a tomato is due to the pigment lycopersicin (lycopin), and the difference between red and pink tomatoes is simply in the skin color. Red tomatoes have a yellow skin due to the presence of carotin, and pink tomatoes have a colorless skin.

In unfavorable seasons tomatoes frequently fail to develop good color. When temperatures are either too high or too low, the red pigment, lycopersicin, fails to develop properly. Poorly colored tomatoes are usually encountered after prolonged hot weather or late in the fall when the weather is cool. In Illinois slow ripening and poor color development are also often associated with excessive vine growth. It is not known whether the poor color development is due to the high nitrogen associated with excessive vine growth or to the lower temperatures prevailing late in the season when the fruits on such plants ripen.

The relationship between the amount of foliage, type of soil, and tomato color and grade has been studied by Gaylord and MacGillivray[5*] in Indiana. They found that a soil fertile enough to develop foliage adequate for protection against strong sunlight was essential to produce a high percentage of No. 1 tomatoes, and that sandy soils in Indiana quite consistently gave lower grade tomatoes than black soils and clays.

Size as Related to Time of Picking

It is ordinarily believed that the fruits maturing earliest are the largest in size. That this is not entirely true is shown by the results in Table 10, which are representative of numerous tests made at the Illinois Station.

TABLE 10.—EFFECT OF TIME OF MATURITY ON WEIGHT OF INDIVIDUAL TOMATO FRUITS, 1935-1937

Period harvested	Early Baltimore	Pritchard	Illinois Baltimore	Marglobe
1935	*lb.*	*lb.*	*lb.*	*lb.*
July 16-31	.31	.34	...	...
Aug. 1-15	.34	.34	.36	.44
Aug. 16-31	.42	.38	.42	.58
Sept. 1-15	.36	.35	.38	.44
Sept. 16-30	.27	.24	.27	.29
1936				
Aug. 1-15	.27	.28	.22	.24
Aug. 16-31	.27	.26	.23	.21
Sept. 1-15	.29	.22	.24	.16
Sept. 16-Oct. 10	.30	.26	.24	.23
1937				
Aug. 11-19	.41	.37	.32	.29
Aug. 20-28	.42	.42	.36	.42
Aug. 29-Sept. 6	.28	.30	.30	.31
Sept. 7-16	.30	.29	.30	.33

Note.—.0625 lb. = 1 ounce.

In four varieties of tomatoes grown in 1935 (Table 10) the weight per fruit increased as picking progressed thru August, and then decreased. In 1936, a drouth season, no definite trend in size of fruits was noticeable. Fruits of Pritchard and Marglobe decreased in size as the season advanced, until the middle of September, while Early Baltimore and Illinois Baltimore increased in size very slightly. There was, however, a very noticeable tendency for the fruits to become larger when production was resumed late in the fall, after the decline in yields (pages 8 to 11) due to excessive temperatures.

Trends in sizes of fruits in 1937 closely resembled those of 1935.

Factors Determining Grade

Official grading has become an integral part of growing tomatoes for the cannery. No attempt will be made to explain the grading system in detail, as this is always done by the cannery fieldmen before the picking season starts. However, many growers do not seem to understand the factors which determine grades. These are mainly degree of ripeness as determined by color, and freedom from blemishes, including cracks, rots, molds, and other injuries. Size also enters into consideration, but is a flexible factor varying with the season.

According to experiments by Gaylord and MacGillivray,[5*] the sequence of ripening takes the fruits thru all the grades. Tomato fruits first grade as culls and U. S. No. 2's because of greenness; then when perfectly ripened, as U. S. No. 1's; and then as the fruits recede in quality because of overripeness, they grade U. S. No. 2, and finally as culls again because of decay. In their experiments tomatoes remained in the U. S. No. 1 condition an average of 6.5 days, the exact time varying with the season from only 2.4 days to 9.6 days. After this period the fruit remained in U. S. No. 2 condition for an average of only 1.9 days, with not much seasonal variation. There was apparently no relation between the length of time the tomatoes remained as U. S. No. 1's and the time they remained as U. S. No. 2's after the No. 1 period. However, the number of days they remained in U. S. No. 1 condition in the field was directly related to the percentage of U. S. No. 1's, the tomatoes from the best fields remaining in good condition the longest. The tomatoes ripening early in the season graded better than those ripening later. Color changes became slower as the fruits approached No. 1 grade. Ripening, as determined by color, tended to slow up materially as the fruits reached the highest grade.

Interpreted in a practical way the work of Gaylord and MacGillivray[5*] means that the grower should not be in too much of a hurry to pick his tomatoes. Green tomatoes are graded down very severely, and there is no excuse for picking them since it is obvious that they will eventually reach the U. S. No. 1 grade if the grower will wait. Tomatoes usually remain in No. 1 condition long enough to give the grower a fair chance to pick them, altho waiting too long is also disastrous because tomatoes remain in the No. 2 stage less than two days before becoming culls.

After-Season Ripening

Many growers find it profitable to pick green tomatoes when there is danger of killing frost and store them until they ripen. Some meet with considerable success, others with consistent failure. Since all growers are left with considerable quantities of green tomatoes in the fall, there is frequent demand for information on the subject. The points which are not well understood are the effect of low temperatures on the fruits, the stage when they should be picked, and the proper method of ripening.

After-ripened tomatoes are not equal in flavor to those that are vine ripened, and are therefore unsuitable for canning. Moreover, such tomatoes do not all ripen at one time, and it is necessary to sort them out two or three times a week, separating those which are ready for use and throwing out the decayed fruits.

In after-ripening tomatoes it is important to store them in a suitable place. A good place is a dark basement where the temperature can be held nearly uniform. The air should be humid in order to prevent shriveling.

The length of time tomatoes will remain in satisfactory condition in storage depends on their ripeness when picked. Green tomatoes will store somewhat longer than those picked when turning, but those picked green are usually insipid in flavor. Green tomatoes stored at approximately 50° F. require about two weeks to ripen and will remain edible for about two weeks after ripening; that is, a total of about four weeks from the time of picking. Tomatoes picked at the turning stage will hold for a total of about 23 days at 50° F. and those picked ripe will hold about 12 days, provided the fruits are in good condition when picked.

Experimental Work.—It is generally believed that tomatoes which are cooled to low temperatures, but not frozen, will fail to ripen properly. Diehl[4*] shows that exposures to a temperature of 32° F. for periods of 1 to 4 days had no effect on the ability of the fruits to ripen, but if the exposure was extended to 8 days the fruit broke down instead of ripening. Wright *et al* [23*] found, however, that tomatoes exposed to temperatures of 32 to 36° F. for periods of 5 to 8 days would ripen, but the rate of ripening was slower than for fruits not exposed.

Diehl[4*] further observed that fruits picked in the turning stage reacted in the same manner as green fruits and, in fact, the area showing red actually increased in size while the fruit was exposed to 32° F. He found that the freezing point for both green and red tomatoes is close to 30.5° F., with some variation between varieties. Green tomatoes which were actually frozen would not ripen later.

Wright *et al*[23*] in later work exposed tomatoes to temperatures as low as 25° F. for periods of 18 to 21 hours, and subsequently these ripened normally. They also observed that mature green tomatoes picked just before a frost in the field ripened in storage more rapidly and developed less decay than those picked the day after a frost.

The stage when green-ripe tomatoes should be picked has been studied by Sando[15*] who found that size of fruit is no indication of how far it has developed toward ultimate ripeness. The number of days from bloom is the only certain indication, maturity being dependent on age, not on size. Sando[15*] divided tomatoes into four stages of ripeness; namely, green, turning, pink, and red ripe. He found that tomatoes picked green and allowed to ripen exposed to air and light differed in flavor and slightly in composition from vine-ripened fruit. Tomatoes picked green were slightly more acid and contained less total sugar. In artificially ripened tomatoes the ripening process, while conforming in general to vine ripening, nevertheless failed to bring the fruits to the same degree of ripeness. In tomatoes which were picked at the turning stage, the ripening process compared much more favorably with vine ripening and the fruits were superior to those picked green. Sando concluded therefore that tomatoes to be ripened in storage should be picked as mature as possible, but that green tomatoes will turn red if properly stored.

Wright *et al*[23*] show that tomatoes picked at the turning stage ripen almost normally when stored at 50° F. Storage at 40° F. prevented ripening at almost any stage of immaturity. The tests showed that the lowest temperature at which ripening with good color and flavor developed was 55° F. The ripening rate increased very materially when temperatures ranged from 60 to 70° F., and Wright recommends these temperatures for fall ripening. Temperatures higher than 70° are not recommended because of the rapid increase of decay. For storing firm fully ripened tomatoes Wright recommends a temperature of 55° F.

VARIETIES FOR USE IN ILLINOIS

Ideas regarding varieties suitable for conditions in Illinois have changed greatly during the past few years. Formerly the belief was held that large-vined, late-maturing varieties were essential if good yields and protection to the fruits from sun scald were to be obtained.

But heavy losses due to excessive vine growth of the late-maturing types in drouth seasons, coupled with the development of better-adapted varieties, have inclined growers toward second-early varieties. When second-early varieties are planted on the heavier soils they produce ample vine growth and return good yields. Consequently in northern Illinois late-maturing varieties for canning purposes have practically been abandoned.

In tests of varieties for northern Illinois by McCollum at the Cook county branch experiment station, the earlier types, including Prairiana which in this test seems later than usual, yielded the most (Table 11). Even in 1937, a highly favorable year for tomatoes, the earlier types

TABLE 11.—ACRE-YIELDS OF MARKETABLE TOMATOES IN VARIETY TESTS AT COOK COUNTY BRANCH EXPERIMENT STATION, DES PLAINES, 1935 AND 1937

Variety	1935		1937	
	Picked first half of picking season[a]	Total yield	Picked first half of picking season[a]	Total yield
	perct.	*tons*	*perct.*	*tons*
Early Baltimore	21.0	12.63	39.1	11.93
Prairiana	9.4	10.55	32.1	16.27
J. T. D.	19.8	9.64	40.0	13.04
Greater Baltimore	12.7	9.44	33.2	12.42
Rutgers	11.0	8.92	32.8	9.14
Marglobe	18.8	8.65	....	....
Illinois Pride	11.3	8.20	....	....
John Baer	34.4	8.14	....	....
No. 500	7.3	7.69	....	....
Canadian	....	....	57.0	7.18
Pritchard	....	....	39.4	10.27
Gulf State Market	....	....	41.8	10.39
Bonny Best	....	....	45.4	11.62

[a]The picking period was divided into two equal parts.

yielded just as well as the large-vined late varieties. In a drouth season these differences would probably be more in favor of the earlier types, as shown in Table 2, page 9.

Fusarium wilt is a considerable factor thruout Illinois and is likely to be serious in any tomato-growing section, even in the northern part of the state.[6*] Such varieties as Chalk's Jewel, Bonny Best, and John Baer, all very similar in type, are highly susceptible to wilt and should be used very cautiously if the disease is suspected to be present. Where the grower has a choice, the resistant types should be planted in preference to any of the susceptible varieties.

Varieties Resistant to Fusarium Wilt

Early Maturing (Second-Early Types)[a]

Break O'Day (red). Foliage very open, fruits globe-shaped, color light orange-red, frequently "puffy" and of poor quality. Fruits subject to excessive sun scald, because of sparse foliage.

Early Baltimore (red). A new introduction in 1935 by the Illinois Agricultural Experiment Station. This variety has proved to be superior in numerous variety tests all over the country. Vine size intermediate (smaller than Greater Baltimore); leaves finely cut. Growth self-determinate, like Pritchard. Fruits large, deeply oblate, and round in cross section. Outside color good, inside color fair or better. Rind thick, and fruits not inclined to crack. Has been bred for drouth resistance. Sets and produces well on dark-colored prairie soils. Owing to its small vines, this as well as other early types, may prove subject to excessive sun scald if planted on light soils where vine growth is restricted because of low fertility.

Prairiana (red). Introduced in 1935 by the Illinois Agricultural Experiment Station. Bred especially for drouth resistance and adaptation on dark-colored prairie soils. Fruits smooth, slightly flattened, bright red in color with thin rinds and numerous cells. Slightly smaller than average. Some concentric cracking. Interior color and quality are excellent. As one of its parents is Earliana, it is likely to have a very restricted vine growth on the lighter soils of low fertility. It should only be planted on the heavier types where the vine growth is ample, if somewhat straggly, but never excessive.

Pritchard (red). Used comparatively little for canning owing to light red color, but very popular with market trade. Fruits medium-sized, globe-shaped, and stand handling well, but tend to decrease in size during latter part of season. Rind is thick, fruit meaty and does not crack severely. This variety is a self-topper and is not subject to excessive vine growth. It may be planted closer than other varieties, and in northern Illinois is being used on the very fertile, dark-colored lower-lying soils.

Rutgers (red). A cross between Marglobe and J. T. D. Tends toward a rather light set in hot, dry seasons. Vine is large, and fruits very similar to Marglobe but somewhat flatter. Quality of the fruit is good, but yields may be low in adverse seasons.

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[a]First-early types, such as Earliana, are seldom grown in Illinois.

STOKESDALE (red). A recent introduction, with fruits very similar to Marglobe. Seems in fact to be an early selection out of that variety. Fruits large and globe-shaped. Vines medium-sized. Has been tested in Illinois, but results are not conclusive. Subject to radial cracks, which may become severe. Claimed to be wilt-resistant, but this is not certain as yet.

Late Maturing[a]

ILLINOIS BALTIMORE (red). Introduced in 1936 by the Illinois Agricultural Experiment Station. A wilt-resistant strain of Greater Baltimore. Differs from that variety, however, in having a deeper, smoother fruit with a thicker rind. Tests in Illinois show that it is superior in yield to Greater Baltimore and tends to retain its foliage better.

ILLINOIS PRIDE (red). Introduced in 1935 by the Illinois Agricultural Experiment Station. Vines large. Fruits very large, solid, oblate, smooth; and stand handling extremely well. Quality excellent.

MARGLOBE (red). No longer used in Illinois for canning, because of uncertain ability to set fruits in hot weather. Fruits globe-shaped, good in quality and size; but yields are erratic. Subject to severe radial cracking.

Varieties Susceptible to Fusarium Wilt

Early Maturing (Second-Early Types)

CHALK'S JEWEL, BONNY BEST, JOHN BAER (red). These are all very similar and there is no constant difference between them. Vines small, and unless planted on fertile soils are apt to be sparse and to cause sun scald. Fruits smooth, fairly solid, medium-sized, varying in shape from oblate to almost globe-shaped, depending on the seedsman's strain. Color and quality generally good. Strains within this group vary about a week in maturity, the general order of maturity being as listed above, but varying according to the strain used. Highly susceptible to wilt, and subject to defoliation diseases.

SCARLET DAWN (red). Vine medium-sized and rather open. Fruits medium-sized, globe-shaped, solid, and of good color. Yield performance in Illinois has not been outstanding.

J. T. D. (red). Slightly later than Early Baltimore and Pritchard, but not quite so late as Greater Baltimore and Marglobe. Fruits large, deeply oblate, but not so deep as Early Baltimore. Outside color good, and inside color very good. Thin wall and numerous seed cells. Free

[a]All varieties subject to excessive vine growth.

from cracks around stem. Vines large and dense, and leaves more finely cut than Early Baltimore. Blossoms inclined to absciss during hot weather. Must be planted further apart than Pritchard, 4 x 5 feet being the usual distance in northern Illinois (where it is grown as a companion variety to Early Baltimore) and on the higher and more rolling fields.

Late Maturing[a]

GREATER BALTIMORE, INDIANA BALTIMORE (red). Vines large, foliage medium heavy. Fruits bright red, flat to oblate in shape, solid, with small cells. The wilt-resistant Illinois Baltimore may be used to replace these.

MATCHLESS, STONE (red). Not much used in Illinois. Replaced largely by wilt-resistant Illinois Pride.

Small-Fruited Types

KING HUMBERT (red). Vine medium-sized; leaves finely cut; sets very heavily. Fruits two-celled, oblong (about 2½ inches long by about 1½ inches across) and borne in clusters. Sets well in hot weather, but contrary to claims it cracks and discolors at the stem end the same as the large-fruited types. Flavor insipid.

PEAR SHAPED (red or yellow). Vines larger than King Humbert, but fruits are shaped like a pear and are not so large. Sets like King Humbert. Subject to cracking.

Altho both of these types set extremely well, tests at Urbana show that the yields are considerably less than those of the better large-fruited varieties.

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[a]All varieties subject to excessive vine growth.

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